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GAINING FROM INTERACTIONS WITH UNIVERSITY: MULTIPLE METHODS FOR NURTURING ABSORPTIVE CAPACITY

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This paper examines the different ways in which firms benefit from their interactions with universities. The paper argues that three learning capabilities, connected with the building up of a firm s absorptive capacity, can be enhanced by interactions with university: explorative, exploitative, and assimilation and transformation capabilities. By looking at a range of potential benefits rising from interactions with university, this paper investigates the impact that some characteristics of firms and university partnerships have on the type of gains that firms obtain from such interactions. To study these issues, we combine data from a survey of UK firms who have taken part in collaborations with university, and data about the past records of partnerships with universities held by our sample of firms

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Keywords
Absorptive capacity, university-industry interactions, firm characteristics.

1. Introduction

The impact of university research on the innovative activities of firms has become a focus of increasing attention from both academics and policy makers. The academic literature has repeatedly documented the positive impact of university-industry interactions on firm's innovative performance (Link and Rees, 1990; Mansfield, 1991; George and Zahra, 2002; Laursen and Salter, 2004; among others). Additionally, support for knowledge transfer initiatives that involve university and industry has become top priority in the policy agenda of many OECD countries (OECD, 2003).

However, the extant literature on the benefits that firms obtain from their interactions with industry suffers from a number of important limitations. One such limitation is that, while it has long been stated that firms' potential benefits from knowledge transfer extends beyond the commercial exploitation of cutting-edge research at universities (Rosenberg, 1991; Florida, 1999; Bercovitz and Feldman, 2007), rare efforts have been made in trying to disentangle empirically the wide range of profits that firms obtain from their interactions with university. In addition to accessing results from high-profile research, the list of potential benefits for firms entails issues such as: assistance in problem solving, training of employees, contribution to downstream activities, or access to information that increases awareness about challenges and opportunities (Gibbons and Johnston, 1974; Rosenberg, 1992).

Another important limitation is associated with the strong focus on large R&D performing firms when examining university – industry collaborations. While a substantial amount of evidence shows that large manufacturing R&D performing firms provide the bulk of the university research funded by industry (HEBCI, 2007), interactions are hardly constrained to this type of firms. As Hughes et al. (2007) show, a large proportion of interactions with universities is held by small, non-R&D intensive and non-manufacturing firms.

The purpose of this paper is to address these issues. We examine the range of benefits accruing to firms from their interactions with university, and the extent to which such benefits differ depending on the characteristics of the firms and the university partners. We do this by combining data from a survey of UK firms that have participated in collaborative projects with university, together with secondary sources of data about both university and industry characteristics.

Finally, this study draws upon the extensive literature on firm's absorptive capacity (Cohen and Levinthal, 1989, 1990; Zahra and George, 2002; Jansen et al., 2005) to conceptualise the different types of benefits that firms obtain from their interactions with university. We propose that such benefits contribute to nurture and expand a firm's absorptive capacity by strengthening three learning processes: a) *explorative* learning; b) *exploitative* learning; and c) the capabilities associated with the *assimilation* and *transformation* of knowledge.

The remaining sections of the paper are structured as follows: Section 2 presents out the literature review and research questions addressed in this paper; Section 3 describes the data, while Section 4 explains the method used; Section 5 presents the results; and, Section 6 concludes.

2. Literature Review and Hypothesis Development

In the last years an extensive amount of government funding has been placed to encourage interactions between university and industry (OECD, 2002; 2003; Mowery et al., 2004). This has been largely justified by the argument that such links help firms to increase awareness of opportunities for commercial exploitation of publicly funded research, and facilitate the transmission of knowledge between academic and industrial scientists, thus contributing to strengthen a country's innovative performance. However, we still know little about how firms benefit from interactions with universities: in particular, to what extent these interactions contribute to industries' innovative activities, and how.

This Section is divided in three parts. We first review the potential benefits on firms' innovative activities that have been generally associated with research conducted at universities. We then discuss how interactions with university might benefit firms by contributing to build up a firm's absorptive capacity. And finally, we discuss some of the factors that are more likely to influence the type of gains firms obtain from their interactions with university.

2.1. The multifaceted nature of the economic benefits from university research

The literature on the economic benefits from scientific research to innovation in industry is huge (see Salter and Martin, 2001, for a review). Our purpose here is not to review this literature, but summarise the different types of benefits that might flow from scientific research, as most frequently suggested by this literature. We suggest that such benefits can be broadly classified in three types.

First, firms can benefit from the 'outputs' generated by scientific research at universities. These outputs include, on the one hand, the contribution of research to fundamental understanding of particular phenomena, as expressed in the form of theories, laws and scientific or technical principles, normally channelled through scientific publications (Gibbons and Johnston, 1974; Salter and Martin, 2001). Indeed, publications and technical reports have been highlighted to be a common source for learning about research conducted in universities among large industrial companies (Arundel et al., 1995; Cohen et al., 2002). On the other hand, the outputs from scientific research at universities also include the generation of new techniques, instrumentation and prototypes (Rosenberg, 1992; Rosenberg and Nelson, 1994; Cohen et al., 2002). These three types of outputs have been rated as contributing importantly to the innovative activities of firms in several industries (Arundel et al., 1995; Cohen et al., 2002).

Second, firms benefit through the contribution of university research to education. One of the main missions of university is its contribution to the generation of highly qualified individuals, educated in science and its methods. Following Gibbons and Johnston (1974), the role that education plays in innovation can be trace through different routes. On one side, a university background education seems to be crucial in facilitating the links of industrial scientists' with the research community and making industrial scientists more susceptible to search for sources of information external to the firm when confronting technical problems in their innovative activities. On the other side, the university education supplies firms with skilled graduates, who 'bring not only a knowledge of recent scientific research but also an ability to solve complex problems, perform research and develop ideas' (Salter and Martin, 2001: 522). As several studies have highlighted, the provision of skilled graduates is one of the primary benefit that flows from university to firms (Gibbons and Johnston, 1974; Florida, 1999).

Finally, the third major contribution flowing from university research to industrial innovation is the direct personal contacts of industrialists with members of the scientific community. The person to person contacts with university scientists act as valuable sources of knowledge that feed into the firms' innovation process by transmitting two different types of knowledge. On the one hand, personal contacts with university scientists contribute to provide direct assistance in problem-solving activities, where university scientists respond to problems posed by industrialists. The requests for advice in problem solving have been reported as critical contributions from university scientist to industrial innovation (Gibbons and Johnston, 1974; Nelson and Rosenberg, 1994). As illustrated by Gibbons and Johnston (1974), the advice and assistance provided by university scientists play a supportive role in the innovation process by helping industrial practitioners to assess the feasibility of projects or providing details of the location of specific information or specialist facilities, among other functions. On the other hand, personal contacts with university scientists contribute to provide new ideas for products or processes, suggesting alternative ways in which problems can be sorted out, and help to increase, among industrial practitioners, awareness about challenges and opportunities related to new business models and technology developments (Bessant et al., 2005).

Personal contacts can be channelled through a large variety of mechanisms. This includes informal mechanisms, such as casual meetings at conferences and workshops, and through direct access to members of well-established networks to the academic community. Very frequently also, personal contacts are channelled through formal arrangements, such as: consultancy agreements, joint research projects and contract research, among others (Cohen et al., 2002; D'Este and Patel, 2007).

2.2. Nurturing absorptive capacity through interactions with university

Our study builds on the concept of absorptive capacity (Cohen and Levinthal, 1989; 1990) by taking a closer look at the benefits received by firms from their interactions with university researchers. We argue that the benefits firms capture from these interactions potentially contribute to strengthening the different components of firms' absorptive capacity.

The concept of absorptive capacity refers to the firm's ability to identify, assimilate and apply to commercial ends knowledge external to the firm. There are two aspects of the absorptive capacity notion that are crucial for this paper: (i) the claim that a firm's absorptive capacity can be created in a variety of ways; and (ii) the premise that a firm's absorptive capacity can be divided into several components.

Regarding to point (i), in their 1990 paper Cohen and Levinthal state that absorptive capacity can be generated in a variety of ways. While they argue that absorptive capacity can be seen as a by-product of a firm's R&D investment, they also acknowledge that manufacturing experience can provide the firm with the background necessary both to recognize and implement new methods. Additionally, Cohen and Levinthal (1990) argue that absorptive capacity can be developed from the firm's deliberate efforts to benefit from personnel exchange and training. In this sense, the focus on R&D as a proxy for absorptive capacity runs in sharp contrast with most of Cohen and Levinthal's (1990) argument that absorptive capacity can be created through a variety of channels.

Cohen and Levinthal (1990) also suggest that, when a firm wishes to acquire and use knowledge that is unrelated to its current knowledge base, the firm must dedicate deliberate efforts to creating absorptive capacity. We propose in this paper that one such purposeful effort to build up and nurture the firm's ability to recognise the value of new, external information, assimilate it and apply it to commercial ends is by establishing linkages with third parties. The firm's accumulated experience in the establishment of linkages with other organisations is likely to play an important role in explaining how well positioned a firm is to exploit technological opportunities. The objective of this paper is to explore how one of such linkages with external organisations (i.e. universities) help firms to enhance learning processes associated to a firm's absorptive capacity.

Some empirical studies have tried to improve upon the operationalisation of absorptive capacity highlighting that internal efforts expand beyond R&D efforts. For instance, Schmidt (2005) proposes that R&D activities *"are not the only building blocks of absorptive capacity"* (p7), instead the organisation and stimulation of knowledge transfer within a firm, along with the employment of qualified human capital are critical in determining absorptive capacity in his study of German firms. Jansen et al. (2005) and Vega et al. (2007) also eschew reliance on simple R&D measures, and instead focus on the role of social integration mechanisms and organisational antecedents in helping to encourage group interaction and assist in the formalisation of procedures and rules, which can have a positive impact on the firm's absorptive capacity. However, there is a relative paucity in research that examines the way in which external sources of knowledge are used by firms to build absorptive capacity, as the focus has been predominantly on internal sources (principally those arising from R&D investment).

With regards to the second point (ii), George and Zahra (2002) have proposed that absorptive capacity is split into two elements *"potential"* and *"realised"* absorptive capacity. While potential capacity consists of knowledge acquisition and assimilation capabilities, realized capacity comprises knowledge transformation and exploitation. George and Zahra (2002) maintain that firms need to build on the different components of absorptive capacity to obtain superior performance.

A later study by Jansen *et al.*(2005) empirically validates the distinction between potential and realised capacity. Their study argues that organisational antecedents are crucial and highlights the importance of certain organisational mechanisms in building absorptive capacity. For instance, they hypothesise that participation in decision making will be positively related to potential absorptive capacity, and that job rotation will be positively associated with realise absorptive capacity. They also examine the impact of systems capabilities (formalisation and routinisation) and socialisation capabilities (connectedness and socialisation tactics) on potential and realised absorptive capacities. Their results reveal that organisational units may differ in their ability to manage potential and realised absorptive capacity and that certain organisation mechanisms can influence this.

We draw upon these studies to operationalise the multiple aspects of absorptive capacity. In particular, we consider three learning processes that can be benefited by interactions with university and help to nurture the firm's absorptive capacity: a) *explorative* learning, b) *exploitative* learning, and c) *assimilation and transformation* learning. In line with the preceding discussion, we propose that 'explorative learning' encapsulates the capabilities developed by the firm to identify sources of information for new ideas, and getting access to sources of knowledge to improve (fundamental) understanding. In contrast, 'exploitative learning' refers to the capabilities developed by the firm to apply knowledge to commercial ends. Finally, we consider together 'assimilation and transformation' as embracing the capabilities developed by the firm to interpret knowledge and facilitate its transmission within the firm's organisation.

Interactions with university might contribute to the building and development of each learning processes. As discussed in sub-section 2.1, university research might contribute to improve the firm's understanding of foundations of particular phenomena, and thus helping firms to develop their explorative learning capabilities. Interactions with universities may also contribute to enhance the capacity of the firm to exploit new or existing knowledge, as in the case in which such interactions permit the development of patentable products or processes, or help to achieve cost reductions in product or process development. Finally, close interactions between university and company personnel may enhance the problem-solving capabilities of firms. Thus, in addition to direct assistance in problem solving from university scientists, both recruitment of skilled graduates and training of firm personnel contribute to enhancing the capacity of a firm to interpret and transmit acquired knowledge within the organisation. Table 1 illustrates the multifaceted features of absorptive capacity, and how interactions with university can potentially contribute to enhance the three learning processes associated with nurturing absorptive capacity.

Table 1. Learning processes and benefits form interactions with university

Learning processes	Sources of information and knowledge from interactions with university
Explorative Learning	Awareness and acquisition of knowledge • Identify sources for new ideas • Access to sources of knowledge providing fundamental understanding
Exploitative Learning	Applying external knowledge to downstream activities • Market introduction of new products • Cost reduction
Assimilation and Transformation Learning	Interpreting and transmitting acquired knowledge • Direct assistance and advice • Recruitment and training

2.3. Factors influencing the type of benefits firms obtain from interactions with universities

In this sub-section we discuss a number of factors that are likely to influence the type of benefits that firms obtain from their interactions with university researchers. We divide these factors in three groups: (i) characteristics of firms (i.e. size and R&D investments); (ii) geographic proximity of interactions; and (iii) characteristics of the university partners (i.e. research quality).

Firm characteristics: Size and R&D

In line with other studies we explore the role of certain firm level characteristics, such as firm size and R&D expenditures, in determining whether firms are particularly likely to benefit from interactions with university in building and nurturing their absorptive capacity. For instance, Sorensen and Stuart (2000) remark how larger (and also older) firms are likely to have higher absorptive capacities due to the accumulation of knowledge and developed routines and processes that allow assimilation and exploitation capabilities. Schmidt (2005) also includes a size dimension in order to capture the possibility of larger firms running multiple innovation projects simultaneously and thus being better able to exploit external knowledge. Conversely, Jansen *et al.* (2005) find that larger firm units lack the flexibility to cope with the acquisition and assimilation components of absorptive capacity, since larger firms may lack the flexibility to acquire and assimilate new knowledge, but find no significantly negative correlation between size and the exploitation component of absorptive capacity. According to this, we would expect that larger firms are more likely to reap benefits, from their interactions with university, associated with the enhancement of ‘exploitative learning’ capabilities, and to some extent with ‘assimilation and transformation’ learning capabilities.

R&D measures are also typically used to study absorptive capacity, such as R&D intensity or presence of an R&D lab (e.g. Veugelers, 1997, Oltra and Flor, 2003, and Schmidt, 2005). Since R&D intensity depicts the degree of firm’s commitment to R&D activities, most studies use this yardstick to argue that firms with higher R&D intensities are more likely to have higher absorptive capacities. However, in line with our argument of the multi-faceted benefits from university-industry interactions, we argue that R&D may have a distinct influence on the type of benefits that firms are likely to obtain from interactions with university. For instance, firms that have high R&D commitments might be more likely to interact with universities with the objective of improving their fundamental understanding and their exploratory learning capabilities, as compared to firms that have little or no R&D investments. However, it is not clear whether firms with higher R&D intensities should be particularly likely to enhance their exploitative learning capabilities or their ‘assimilation & transformation’ capabilities as a consequence of their interactions with university, as compared to firms that are less R&D intensive or conduct no R&D at all.

Finally, as Schimdt (2005) has pointed out, it is important to distinguish whether firms conduct R&D on a continuous basis, as opposed to not conducting R&D at all or investing in R&D only occasionally. Since accumulated knowledge is critical to the notion of absorptive capacity, firms that are continuously involved in R&D activities should have developed skills and experience that place them in a favourable position to value external knowledge, assimilate it and apply it to commercial ends (as compared to companies with no or discontinuous R&D activities). In this sense, we would expect that firms conducting R&D on a continuous basis are more likely to reap benefits from their interactions with university associated with all three types of learning capabilities.

Geographic Distance

It is widely acknowledged that geography strongly influences the sources of knowledge available to organisations. Beginning with the work by Jaffe (1989) there has been a strong focus on exploring the role of geographic proximity in shaping the relationship between private innovative activities and university research. Jaffe's research examined the extent to which spatially mediated R&D spillovers influence the generation of increased innovative output (measured by corporate patents) at the US state level. One of the key findings from this study was that corporate patenting responds positively to knowledge spillovers from academic research. Feldman's (1994) research concentrated on the co-location of complementary resources and her results illustrated how innovation is a function of an area's technical infrastructure: innovation is positively related to geographic concentration of industrial and university R&D expenditures and to the presence of related industry and business services. This suggests that the co-location of complementary resources can supply economies of scope, which encourage innovation and product commercialisation. Furthermore, these empirical results confirm that university R&D activities enhance technological opportunities available in a region or state, which provide the incentives to invest in private industrial R&D, in order to exploit basic scientific knowledge. As a result the innovation outputs of industrial firms can be shaped by the spatial landscapes in which they operate. Also Storper and Scott (1995) and Storper and Venables (2004) highlight that certain types of knowledge or technology may also require geographic proximity: when there is uncertainty about the future and nature of a technology or market, face-to-face contacts are particularly needed to exchange ideas.

The impact of geographic distance in shaping university – industry collaborations in particular, has appeared prominently in empirical studies, many of them based on innovation surveys (Mansfield and Lee, 1996; Arundel and Geuna, 2004, among others). For instance, Arundel and Geuna (2004) examine how the role of distance in the collaboration between business and public research organisations is affected by the type of knowledge sought. Their results confirm that those firms seeking codified knowledge (i.e. publications and patents) are less likely to find geographic proximity of importance.

In short, these studies suggest that when firms interact with universities in order to enhance their 'exploitative learning' capabilities or to work jointly with university scientists in order to get assistance in problem solving activities, which require extensive face-to-face interaction and human mobility, firms are likely to interact with geographically close universities. Therefore, we would expect that geographic proximity between the firm and its university partners is likely to be positively related to the enhancement of both 'assimilation and transformation' and 'exploitative learning' capabilities.

The quality of research of university partners

The attributes of the university partners themselves are likely to influence the type of benefits firms obtain from their interactions. One of the attributes that has drawn the attention of much research in this field has been related to the quality of the research conducted at the university departments with which firms interact (Mansfield and Lee, 1996; Abramovitz et al., 2006).

Mansfield and Lee (1996) find that 'second tier' departments play a very important role on industrial innovation, since a substantial proportion of findings from academic research considered by firms as important in product and process development corresponded to not-prestigious departments. The effects of faculty quality are extremely noticeable in basic research departments, where top-ranked departments display the largest share of funding supported by industry, as compared to applied research departments, where faculty quality seems to have a much more moderate effect on the probability that a firm would support R&D there.

The findings of Abramovitz et al. (2006), who examine the extent to which business sector R&D activity is located in the vicinity of university research departments, indicate that the role of high-quality research departments vary across industries. Only in the case of pharmaceuticals and chemical industries there was clear evidence of co-location between R&D activity and top quality departments; while for machinery and communications equipment the strong geographic co-location was with low ranked departments.

Building upon this research, we contend that top quality departments might be particularly likely to attract highly R&D intensive firms and those firms interested mainly in accessing research findings that contribute to fundamental understanding. While firms driven by the access to specific knowledge and expertise to solve technical problems, may be more inclined to second-tier departments. As Lee and Mansfield (1996) argue: ‘The major research universities have formidable capacities and strengths, but at the stage where firms need to interact with university personnel who are willing to focus on their immediate problems and help them apply new knowledge, less prestigious universities may have a comparative (…) advantage’ (: 1057).

3. Data Sources

This papers draws upon two different data sources. On the one hand, the paper uses data from a survey of firms that collaborated with university. On the other hand, data from the university partnerships that the firms responding to the survey established in the past. This section describes in detail these two sources of data.

3.1 Survey

In order to investigate the research questions put forward in Section 2, we use a specially designed survey targeted at researchers within firms that have had research collaborations with universities. The scope of our survey is slightly different as compared to others such as the ‘Carnegie-Mellon’ (CMS) survey (Cohen *et al.* (2002)), the ‘PACE’ survey (Arundel et al., 1995) or the Community Innovation Survey (CIS) (DTI 2005), in at least two respects.

First, while the CIS and PACE surveys concentrated on obtaining information about a wide range of innovative activities within a firm, only a part of which was focused on interactions with research undertaken in universities and other public sector institutions, the focus of our survey is precisely: *the nature and extent of university-industry collaborations*. Secondly, while the ‘Carnegie-Mellon’ and ‘PACE’ surveys were addressed to R&D active firms in industry sectors, our survey was directed at individual personnel within firms who had undertaken some form of collaborative activity with a partner in a university: therefore, our population of firms includes R&D active and not R&D active firms, as well as firms in the manufacturing and the service sector.

While our survey has a comparatively narrow focus (i.e. just looking at firms collaborating with university), it does obtain, in exchange, information about a wide range of detailed aspects of firm - university interactions. In particular, the survey collects data on: a) the type of collaborations; b) the incentives and barriers to collaborative activity, and c) the outcomes or benefits from such collaborations. In this sense, this survey allows us to analyse the fine grained nature of university - firm interactions in terms of the various benefits that can arise from collaboration between the two types of partners.

In order to identify researchers within firms who have had collaborations with university, we use information from the records of grants awarded by the UK Engineering and Physical Sciences Research Council (EPSRC) for the period 1991-2003.[1] Only grants involving partnership between university researchers and personnel based within firms were considered. This led to a sample frame of 2095 firm units,[2] distributed in industry sectors as depicted in Table 1 below.

Table 1 shows that our sample of 2095 firms displays a slightly different distribution across sectors, as compared to the distribution of firms from the UK Community Innovation Survey.[3] For instance, Chemical & Chemical Related, Instruments, Computer Services and Business services are overrepresented in our sample, while industries such as Textiles, Food & Beverages and Mining & Quarrying (all included

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[1] The EPSRC distributes funds on the basis of research proposals, mainly from university-based investigators, in response to open calls for applications. It distributes some 20-25% of the total UK science budget. The EPSRC actively encourages partnerships between researchers and the potential users and beneficiaries of research. Partners may include people working in industry, government agencies, local authorities, National Health Service (NHS) Trusts, non-profit organisations, research and technology organisations and the service sector. Almost 45% of EPSRC funded research grants involve partnerships with industry or other stakeholders.

[2] In order to minimize the risks of mailing questionnaire to wrong addresses, we constrained the sample to company personnel named on EPSRC grants between 1999 and 2003 only.

[3] We draw upon data from the UK CIS-4. The survey was implemented in 2005, sampling over 28 thousand UK enterprises, covering enterprises with 10 or more employees in sections C-K of the Standard Industrial Classification (SIC) 2003. Valid responses were received from 16,446 enterprises, yielding a response rate of 58%. For more details on the UK Innovation Survey, see: www.dti.gov.uk/innovation/innovation-statistics/cis/cis4-sample

within Manufacturing n.e.c.) are under-represented. This different distribution clearly highlights that the firms involved in the type of interactions with university (in particular, those interactions mediated through EPSRC collaborative grants) are not randomly distributed across the manufacturing and service sectors but are more likely to come from certain sectors (e.g. Chemicals and Computer services) rather than others (e.g. Utilities and Construction, Machinery and Metals or Wholesale and Retail trade service firms).

Table 1: Distribution of the 2095 surveyed firms across sectors compared to distribution of firms from the UK Innovation survey

Industry	Proportion of surveyed firms by sector	Proportion of firms by sector in UK (CIS data)
Chemicals & Chemic. Related	9.1	4.6
Electrical/Electronics	8.6	2.5
Instruments	6.9	1.4
Machinery/Metals	9.8	10.1
Transport	4.6	1.4
Utilities & Construction	6.4	14.6
Manufacture n.e.c.	8.7	13.3
Computer Services	7.6	5.4
Research & Development	6.7	3.2
Other Business Services	12.9	21.8
Services n.e.c.	18.6	21.7
Total	*100%*	*100%*

Note: Chemicals & Chemical related include firms in sectors such as Manufacture of Chemical and Chemical products, Manufacture of rubber and plastic products and manufacture of other non-metallic mineral products (ISIC codes 24 to 26). Electrical/Electronics include: Manufacture of electrical and optical equipment, manufacture of electrical machinery, and manufacture of radio, tv and communication equipment (ISIC 30-32). Instruments include Manufacture of medical, precision and optical instruments (ISIC 33). Machinery/Metals include Manufacture of basic metals and fabricated metal products and Manufacture of machinery and equipment (ISIC 27-29). Transport includes Manufacture of transport equipment (ISIC 34-35). Utilities & Construction include Electricity, gas and water supply and Construction (ISIC 40-41 and 45). Manufacture not elsewhere classified includes Mining and Quarrying, Manufacture of food products, beverages and tobacco, Manufacture of textile products, Manufacture of wood products, among others. Computer Services include Computer and related activities (ISIC 72) (including Hardware and Software Consultancy and maintenance and repair of office computing machinery, among others). Research & Development includes Research and Development (ISIC 73). Other Business Services include Other business activities (ISIC 74) (including engineering and technical consultancy, technical testing and analysis and accounting among others). Services n.e.c. include Wholesale and retail trade, Hotels and Restaurants, Financial intermediation, etc.

We dispatched 2095 postal questionnaires in May 2004 and in July 2004 reminders were sent. Also we contacted by telephone researchers from some of the companies for which telephone contacts were available in our raw data on collaborative grants. By September 2004, 478 completed questionnaires had been received, giving us a response rate of 22.8%. This response rate ranged between 13.6% (i.e. Services n.e.c.) and 33.5% (i.e. Chemicals and Chemical Related).[4]

3.2. Past partnerships

The other source of data we use in this paper comes from the records of past collaborations as recorded in the EPSRC collaborative grants over the period 1991-2003. On the basis of the company names and postcodes, we matched our set of 478 survey respondents with the information from the grants awarded by the EPSRC. This resulted in a total of 2695 partnerships between our set of responding firms and UK university departments. Since these data allows us to identify the university partners (i.e. department and university names), it allows us to gather information related to the interaction itself (such as the distances between companies and university partners) as well as on some characteristics of the university partners (e.g. whether the university department is a top or low-ranked department in terms of research quality).

One feature that is worth highlighting from these 2695 partnerships refers to its disciplinary composition. As mentioned at the beginning of this section, the raw information from these partnerships comes from the grants awarded by the UK Engineering and Physical Science Research Council (EPSRC). Most of these partnerships are therefore with researchers in fields of research that fall within the main remit of EPSRC: that is, physical sciences and engineering. Table 2 shows the composition of disciplinary fields of the university partnerships established by our set of survey responding firms (as recorded by the EPSRC awarded grants). As Table 2 shows, over 60% of the partnerships were established with engineering-related departments.

[4] The response rate for each of the 11 sectors was as follows: Chemicals and Chemical Related, 33.5%; Electrical and Electronics, 19.3%; Instruments, 26.9%; Machinery and Metals, 26.2%; Transport, 17.5%; Utilities and Construction, 27.8%; Computer Services, 19.5%; Research and Development, 21.4%; Other Business Services, 27.6%; Manufacture n.e.c., 21.9%; and Services n.e.c., 13.6%.

Table 2. Proportion of past partnerships by discipline

Discipline	% of partnerships
Chemical Engineering	5.0
Chemistry	8.5
Civil Engineering	8.6
Computer Service	6.8
Electrical and Electronic Engineering	12.8
General Engineering	10.0
Mathematics	2.0
Mechanical, Aero. and Manuf. Engineering	19.5
Metallurgy and Materials	9.5
Physics	5.3
Others (including Biology and Medicine, among others)	12.0
Total	100%
Number of partnerships	2695

4. Variable description and method

4.1. Dependent variables

Since we are interested in benefits arising from firm-university interactions as a means of nurturing a firm's absorptive capacity, we construct a number of dependent variables in order to reflect the multifaceted nature of benefits from university-firm interactions. To build our dependent variables, we draw upon a particular section of the questionnaire that asks companies to report their assessments about the importance of a list of benefits from their interactions with university. In this section, firms were asked to assess on a 5 point Likert scale (ranging from not important to extremely important) the following 9 benefits: 1. 'Improve understanding of foundations of particular phenomena'; 2. 'Source of information suggesting new projects'; 3. 'Generation of patents (in products or processes)'; 4. 'Assistance in problem solving'; 5. 'Recruitment of university postgraduates'; 6. 'Training of company personnel by university researchers'; 7. 'Contribution to the successful market introduction of new products / processes'; 8. 'Cost reduction in product or process development' and 9. 'Reducing the time required for completion of company's R&D projects'.

Table 3 shows the correlation matrix for the resulting 9 benefit-items. The 9 benefit-items are, for the large part, weakly correlated with each other. The large majority of the bi-variate correlations are below 0.4, with some exceptions. On the one hand, the correlation between ‘recruitment’ and ‘training’ (i.e. 0.409); on the other hand, the correlations between the items ‘Contribution to the successful market introduction of new products / processes’, ‘Cost reduction in product or process development’ and ‘Reducing the time required for completion of company’s R&D projects’. These latter three items have been grouped together in a new variable, since the resulting scale was reliable (α = 0.71).[5] We have called this new variable: ‘downstream-related’ benefits.

Table 3. Correlation Matrix for the Dependent Variables

	2	3	4	5	6	7	8	9
1. Improved understanding	0.280	0.334	0.135	0.157	0.289	0.149	0.189	0.121
2. Information	---	0.334	0.136	0.180	0.356	0.344	0.289	0.286
3. Problem Solving		---	0.096	0.226	0.226	0.223	0.310	0.314
4. Recruitment			---	0.409	0.120	0.094	0.099	0.114
5. Training				---	0.185	0.201	0.260	0.251
6. Patents					---	0.344	0.359	0.282
7. Market introduction						---	0.430	0.424
8. Time required							---	0.508
9. Cost reduction								---

Correlation coefficients are always significant at the 5% level. In calculating these correlations, we have used the raw responses in the questionnaire using the five point Likert scale for each benefit item. We have used all 478 cases to calculate these correlations; however, due to missing data, the number of observations slightly differs for each pair of variables.

We have considered the resulting 7 benefits independently, in order to investigate the conditions that favour certain types of benefits from interactions with university. We have created 7 dichotomous variables, reflecting the assessment attached to each of the 7 benefits. The criteria to codify the responses was as follows: 0, if the firm assesses the item as unimportant or slightly important, and 1, if it assesses the item as moderately, very or extremely important (Table A2 in the Appendix shows the proportion of firms assessing each benefit according to this codification for each of the 7 dependent variables).

We have conceptually grouped the resulting 7 benefit items in three categories, consistently with our discussion in Section 2.[6] Therefore, we argue that: ‘improve understanding’ and ‘sources of information’ are benefit-items that can be associated with the enhancement of firm’s *explorative* learning capabilities; ‘problem solving’, ‘recruitment’ and ‘training’, with *assimilation and transformation* learning

[5] A Cronbach’s alpha coefficient, examining the reliability of a scale, shows that the new variable has a relatively high internal consistency: Cronbach’s alpha coefficient is 0.71.
[6] Data reduction techniques, such as exploratory Factor Analysis, did not help to identify higher level factors.

capabilities; and ‘generation of patents’ and ‘downstream-related’ with *exploitative* learning capabilities.

4.2. Independent Variables

Consistently with our discussion in Section 2, we consider a number of independent variables, which we define below. Firstly, *Firm size* defined as the natural logarithm of the number of employees in the firm. A logarithmic transformation was used given the highly skewed nature of the distribution of this variable: 26% of business units in our sample have 20 or less employees, and 10% have more than 2000 employees (with a median of 70 employees and an average of 3128). Manufacturing sectors have a much larger average firm size compared to service sectors, and the median firm size ranges from a lowest level of 22 employees, for Research & Development firms, to a highest level of 2200 for business units in Transport.

We have considered two variables related with the extent to which the firm has been engaged in R&D activities. On the one hand, we have considered *R&D intensity*, which was calculated by the ratio of R&D employees to total employees. Of our sample of business units, 15% have no R&D expenditures, and 30% of the business units have R&D intensity equals to 2% or less (with a median of 8% and an average of 23%). R&D intensity also differs significantly across our set of sectors: excluding of R&D services (for which the average R&D intensity is 60%), average values range from 10% in the case of Construction and Utilities to 34% in the case of Computer Services.

On the other hand, we have also considered whether the firm has conducted R&D on a continuous basis *ContR&D*, as opposed to have been involved on a discontinuous basis or not at all, over the period 2002-2003. 72% of the firms in our sample engaged in R&D on a continuous basis, a percentage that differs significantly across sectors: ranging from a lowest value of 54% for Services n.e.c. to a highest value of 92% for Instruments. *Firm size*, *R&D intensity* and *ContR&D* were computed on the basis of the data collected by our survey (the first two referring to the year 2003).

We have also considered the role of geographic distance in influencing the benefits accrued by firms from their interactions with universities. This is captured by *distance* and is calculated as the average distance (expressed in Km) between the firm's unit location and the location of all universities with which the firm established research partnerships as reported in the records of EPSRC collaborative grants, over the period 1993-2003. The exact distance between a company and each of its university partners was calculated on the basis of the postcodes of both the firm's unit and the universities with which the firm has collaborated.[7]

The data on distance indicates that 75% of interactions established between our sample of firms and universities are below a distance of 241Km. This figure varies by sector, ranging from a lowest of 193Km for Electrical and Electronics to a highest value of 303Km for Transport. For the whole sample of business units, only 17% of the interactions established with universities, through the EPSRC collaborative grants scheme, are located within the range of 50Km.

Based also in the past records of collaborative grants with universities in which our sample of business units have participated, we also examined some characteristics of the university partners involved in past collaborations. In particular, we have used an indicator for the quality of the research conducted within the departments involved in those collaborations, by gathering information from the results of the two most recent Research Assessment Exercises (RAEs) in the UK (conducted in 1996 and 2001). The primary purposes of the RAE is to provide ratings of research quality to be used by the UK higher education funding bodies in determining the main block grants for research to the institutions they fund. Each university submits the results of their research activity for assessment on all or some fraction of the research staff in departments of their choice within 68 subject research areas (though submissions to the RAE are not mandatory, the incentives for participation are high as public research funding depends on the assessment). Each department submission is rated within a seven-point scale ranging from 1 to 5* - with 5* being the top rate, meaning that the research quality of a department reaches international excellence in more than

[7] The distances were collected by using the GRIDLINK database which links postcodes to grid values. These grid values have a geographical positioning accuracy of within 100 metres. The grid values allow us to estimate the linear distance between two grid points using postcodes. Therefore we were able to measure the geographic distance between each firm in the survey and the universities with which it collaborates. We thank Dr Toke Reichstein (CBS) and Dr Ammon Salter (ICL) for this data and methodology.

half of the research activity submitted, and attainable levels of national excellence in the remainder.[8]

Using the RAE information on department ratings, we recodified the rating scale into 1 to 7,[9] and constructed two dummy variables. On the one hand, the variable *top,* which takes the value 1 when the university departments with which a firm has collaborated have an average ranking value of 6.5 or above; and zero, otherwise. On the other hand, the variable *medium*, which takes the value 1 when the university departments with which a firm has collaborated have an average ranking value ranged between 5.5 and 6.49 (and zero, otherwise). The reference category being composed by those firms for which the average ranking of their university partners corresponded to the lowest categories of research quality (i.e. below 5.5).

Of the overall 2695 partnerships established by our sample of 478 business units on the basis of EPSRC collaborative grants over the period 1993-2003, about 36% were with departments ranked in the low categories; 36% in the medium category; and 28% in the top category. These percentages vary across sectors. The proportion of low-ranked departments is particularly high in the Computer Services and the Manufacture n.e.c., with about 50% of the interactions taking place with low-ranked departments. While the proportion of top-ranked departments is particularly high in the case of Electrical & Electronics, with 40% of interactions with this type of departments.

We include industry dummies and regional dummies,[10] as well as a categorical variable which equals one if the firm is a subsidiary or a division of a larger company (*part of a larger company)*, and a variable capturing the number of partnerships with

[8] RAE results for 2001 and 1996, together with the definition of the ratings, are publicly available at http://www.hero.ac.uk/rae/Pubs/index.htm. For instance, a rate of 5 is defined as: "quality that equates to attainable level of international excellence in up to a half of the research activity submitted and to attainable levels of national excellence in virtually all of the reminder". While a rate of 4 is defined as: "quality that equates to attainable levels of national excellence in virtually all of the research activity submitted, showing some evidence of international excellence". With a rate of 1 defined as: "quality that equates to attainable levels of national excellence in none, or virtually none, of the research activity submitted".

[9] Turning the original 1, 2, 3b, 3a, 4, 5 and 5*, into the corresponding following values: 1, 2, 3, 4, 5, 6 and 7.

[10] Manufacture n.e.c. and Northern Ireland, Scotland and Wales being the reference categories, respectively. Dummies include all the other ten sectors considered in this study, and 9 UK regions – East Midlands, East of England, London, North West, North East, South West, South East, West Midlands and Yorkshire & Humberside.

university that the company has had in the past through EPSRC collaborative grants (transformed logarithmically; *number of partnerships*). Details for all the variables are summarised in Table A1 of the Appendix.

4.3. Method

Finally, as mentioned above, since the dependent variables were translated into dichotomous values (0 or 1), to indicate the degree of importance attached by the firm to each type of benefit, we have used techniques for binary outcomes: i.e. Logistic Regressions. The coefficients can be interpreted in terms of odds ratio or marginal effects (Greene, 2000; Long and Freese, 2006). The raw estimates are shown in Section 5. We have also conducted a robustness check by using a Multivariate Probit Model (MPM). The MPM allows the error terms to be correlated across equations and therefore to account for the fact that our seven dependent variables might not be independent with one another. The results of the MPM are reported in the Appendix.

5. Results

This section reports the results of our analysis.

5.1. Benefits from interactions with university

Table 4 shows the percentage of respondents that assessed each of our 7 benefit-items as moderately, very or extremely important (i.e. ticked 3, 4 or 5 in the scale), ranking the 7 items in order importance.

Table 4: Proportion of firms assessing each benefit as moderately, very or extremely important

Benefits from interactions with university	**% of firms**
Assistance in problem solving	67.3
Improve understanding	66.7
Sources of information for new projects	57.5
Recruitment of postgraduates	42.0
Downstream-related activities	29.3
Training of company employees	27.4
Generation of patents	20.0

As Table 4 shows, the two benefits from interactions with university that are ranked as most important are ‘problem solving’ and ‘fundamental understanding’. It is important to highlight that almost the same proportion of researchers attach a high importance to these two items, showing that firms do not only benefit from university by getting access to research outputs and gaining better understanding. Equally, firms benefit from knowledge exchanges oriented to provide direct assistance in problem solving activities - characteristic of a two-way knowledge transfer model. Moreover, a non-negligible proportion of firms (almost 30%) consider that links to university have been important to their downstream activities, as illustrated by the contribution of interactions with university in the successful market introduction of new products.

When the assessments are examined across industry categories we observe that there are substantial differences in how firms in different industries assess benefits. For instance, as Table 5 below shows, while the Transport and Chemical & Chemical Related sectors show the highest proportion of firms assessing 'fundamental understanding' as the key benefit, it is Research & Development Services that has the highest proportion of firms assessing 'recruitment of postgraduates' as the key benefit, and Utilities & Construction the one that has the largest proportion of firms assessing 'problem solving' as the most important benefit. It is also important to note that Transport firms are the ones that have a largest proportion of firms assessing benefits as important across a wider range of benefits, while Computer Services show the lowest proportion of firms assessing benefits as important in a wider range of benefits.

Table 5: Proportion of firms assessing each benefit as moderately, very or extremely important, breakdown by sector

	Explorative learning		Assimilation & Transformation			Exploitative Learning	
	Information	Improved Understand.	Problem Solving	Recruit.	Training	Patents	Downstream Related
Chemical & Ch. Related	62.9	79.0	69.4	35.5	37.1	25.8	30.6
Electrical/Electronics	51.4	77.1	62.9	54.1	40.0	20.0	40.0
Instruments	57.9	71.1	60.5	38.9	**10.8**	18.4	31.6
Machinery/Metals	**66.7**	62.3	67.9	32.1	30.2	26.4	45.3
Transport	64.7	**88.2**	70.6	64.7	**47.1**	**29.4**	**47.1**
Utilities & Construction	48.6	73.0	**89.2**	48.6	32.4	**8.1**	24.3
Manufacture n.e.c.	60.0	50.0	77.5	**25.0**	25.0	27.5	30.0
Computer services	**48.3**	**48.3**	**37.9**	41.4	17.2	10.3	20.7
Research & Dev.	**48.3**	62.1	55.2	**65.5**	24.1	20.7	20.7
Other Business Services	54.8	67.1	71.2	41.1	21.9	16.4	**15.1**
Services n.e.c.	61.2	59.2	65.3	45.8	22.9	17.0	29.8
Total	***57.5***	***66.7***	***67.3***	***42.0***	***27.4***	***20.0***	***29.3***

Note: we have indicated in bold those figures that are at the top and bottom range within each type of benefit item.

5.2. Factors associated with the different types of benefits

Consistently with our discussion in the previous sections, we examine the factors that influence the different ways in which firms benefit from their interactions with university. Table 6 reports the results for each of the 7 type of benefits from interactions with universities. The results show that each benefit is associated with a different set of explanatory factors. Looking at each of our explanatory variables in turn, the results are reported as follows.

Firm size does seem to play a significant role in influencing the extent to which firms reap benefits associated with hiring skilled personnel, and to a lesser extent with regards to accessing sources of information and obtaining benefits associated to their downstream activities. Our results are especially strong with respect to 'recruitment' of postgraduates, suggesting that larger firms are particularly well positioned to attract highly skilled labour.

With regards to firms' involvement in R&D activities, it seems important to distinguish between R&D intensity and being involved in R&D on a continuous basis. With regards to the former, R&D intensity has a significantly positive impact only in the case of benefiting from the 'recruitment' of postgraduates (and a positive but not statistically significant impact in the case of 'improved understanding'). Therefore, among firms that collaborate with university, R&D intensity does not provide a distinctive advantage in terms of reaping benefits associated with the enhancement of exploratory learning capabilities.

However, being involved in R&D on a continuous basis does seem to have a more widespread effect on the probability of obtaining a wider set of benefits from interactions with university. Almost all the estimated coefficients associated with continuous R&D are positive and high, though in only three cases they are statistically significant: 'improved understanding' and generation of 'patents' and to a lesser extent, 'training' of firm's employees. For instance, a continuous R&D performer is three times more likely to assess 'improved fundamental understanding' as an important benefit compared to a firm that does not conduct R&D on a continuous basis.

In brief, these results highlight that more than the extent to which firms engage in R&D, it is the persistency of their involvement what seems to matter. This is consistent with the findings from Schmidt (2005), suggesting that more than the current R&D expenditures as a share of turnover, it is the cumulative nature of engagement in R&D what influences a firm's absorptive capacity. Also, these results highlight that, among firms that interact with university, R&D intensity does not seem to have a significant impact with respect to the large majority of the possible benefits derived from interaction with university, pointing out that firms might obtain a wide range of benefits with comparatively low levels of R&D intensity.

With respect to distance, the results reported in Table 6 show that firms that have established geographically closer collaborative partnerships with universities are more likely to assess 'assistance in problem solving' as an important benefit. This reflects the importance of geographical proximity for the transfer of tacit knowledge associated with problem solving activities. For instance, on the basis of the estimates shown in Table 6, we can interpret that a decrease of 50Km in the distance with a university partner increases the probability of assessing 'problem solving' as an important benefit by 10%.

While this result is partially in line with our expectations, geographical proximity does not seem to play a significant role with regards to any of the other benefits related to the building of 'assimilation and transformation' learning capabilities, nor those related to 'exploitative learning' capabilities.

With respect to the research quality characteristics of the university departments with which firms have established partnerships, the results reported in Table 6 reveal the following. Those companies that dominantly collaborate with medium-ranked departments do not exhibit a higher probability of benefiting from any of the items considered in this study (with the only exception of benefits associated to access to 'information', though this result is only weakly significant). While collaborating with top-ranked departments increases the probability of obtaining benefits from interactions with university with respect to: 'training of firm's personnel', generation

Table 6: Factors that influence firms' assessment of benefits from interactions with university as important (Logistic Regressions)

Variables	Understanding	Information	Problem Solving	Recruitment	Training of firm's personnel	Patents	Downstream activities
Firm Size (LN employees)	-0.050	0.107 *	0.110	0.242 ***	0.094	-0.016	0.118 *
	(0.068)	(0.064)	(0.070)	(0.068)	(0.069)	(0.080)	(0.069)
R&D Intensity	0.123	0.080	-0.659	0.929 **	-0.247	-0.516	0.093
	(0.475)	(0.418)	(0.436)	(0.434)	(0.474)	(0.531)	(0.470)
Continuous R&D	1.104 ***	0.088	0.408	0.347	0.614 *	1.364 ***	0.084
	(0.292)	(0.268)	(0.299)	(0.291)	(0.318)	(0.418)	(0.305)
Distance (Km)	-0.001	0.0003	-0.002 **	-0.0005	-0.0003	0.0003	0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Medium Rank Univ. partners	0.146	0.392 *	0.321	-0.017	0.377	0.187	0.120
	(0.256)	(0.234)	(0.257)	(0.251)	(0.278)	(0.331)	(0.272)
Top Rank Univ. partners	0.179	0.356	-0.170	0.439	0.702 **	1.177 ***	0.716 **
	(0.335)	(0.305)	(0.328)	(0.324)	(0.352)	(0.390)	(0.342)
Number partnerships (LN)	-0.149	0.260	-0.146	0.177	0041	0.277	-0.062
	(0.171)	(0.162)	(0.168)	(0.164)	(0.173)	(0.192)	(0.173)
Part of larger company	0.871 ***	0.090	0.124	-0.073	0.049	0.512	-0.013
	(0.265)	(0.240)	(0.258)	(0.255)	(0.280)	(0.327)	(0.274)
Intercept	-1.303 **	-0.990 *	0.767	-2.397 ***	-1.683 ***	-2.642 ***	-1.561 **
Industry & Region Dummies	Included	Included	Included	Included	Included	Included	Included
Number of observations	420	421	420	419	419	419	419
Log Likelihood	-239.5	-275.8	-244.4	-251.7	-222.6	-181.0	-229.1
Pseudo R2	0.19	0.08	0.14	0.20	0.14	0.19	0.14

Note: Two tailed t-tests: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Standard errors in parentheses.

of ‘patents’ and ‘downstream-related’ activities. For instance, firms that dominantly interact with top-ranked departments are two times more likely to assess benefits associated to ‘downstream related activities’ as important.

It is interesting to note, however, that the impact of top-ranked departments is not substantially different with regards to ‘improved understanding’ or access to sources of ‘information’ for new ideas as compared to the impact of collaborating with low-ranked departments. These results, therefore, run somehow in contrast with our expectations discussed in Section 2. In short, for a substantial proportion of the benefits associated to interactions with university, firms benefit indistinctly, regardless off whether they dominantly interact with top-ranked or lower-ranked departments.

With regards to other firm level characteristics, we also included a categorical variable for subsidiaries and a variable capturing the scale of past partnerships with university. The former variable has a positive and insignificant impact on the probability of assessing ‘improved understanding’ as important benefits from their interactions with university. This result reveals that those firms which are part of larger companies are more likely to perceive benefits associated to the enhancement of exploratory learning capabilities. However, the number of partnerships with universities held by the firm does not appear to be a significant factor in explaining the assessment of benefits as important.

6. Discussion and conclusion

Much research has been devoted to the outcomes of absorptive capacity, but little is known about the factors that contribute to build and nurture the absorptive capacity of firms. This study has attempted to shed some light into this topic. We have examined the extent to which firms’ characteristics and certain features of university-industry linkages influence the type of benefits that firms obtain from their interactions with university.

Our results reveal that firms benefit through very different ways from their interactions with university. Firms value not only the improvement of their understanding of the foundations of particular phenomena that results from the access to the outputs of scientific research. They also assess as important the direct assistance in problem solving that academic researchers are able to provide, as well as, the access to skilled personnel through recruitment, and the contribution of interactions with university to the enhancement of firms' downstream activities.

Our results also show that different benefits seem to be driven by different types of factors. For instance, it becomes clear from our results that few of the benefits from interactions with university are explained by the level of firm's R&D intensity. The impact of R&D intensity seems to be largely constrained to accessing highly skilled personnel. In other words, these results reveal that *among* firms that collaborate with universities, R&D intensity does not discriminate between those firms that benefit strongly from those that do not benefit at all, for the large majority of benefit types.

This statement, however, has be to be qualified in two important ways, since the implication is not that R&D is unimportant. On the one hand, our sample of collaborating firms is characterized by being highly R&D intensive, on average. It is likely that being R&D active does matter for interaction (as many studies have shown). What we are examining here is a different issue: we investigate whether, among those firms that do interact with university, R&D intensity has a significant impact in the extent to which firms assess gains from interaction as important. And such impact seems to be crucial for only a restricted set of benefits. On the other hand, conducting R&D on a continuous basis does seem to have a stronger impact when compared to R&D intensity. This supports the argument that the acquisition of a minimum knowledge base through R&D investment, positions the firm more favourably to benefit from interactions with university.

In short, the results of this study with respect to the impact of R&D expenditures reflect the multifaceted character of absorptive capacity building. Firms with very different levels of R&D may benefit similarly from their interactions with university, and in order to accessing certain types of benefits from interactions with university (such as direct problem solving), high levels of R&D do not seem to be a prerequisite.

Our results also show that geographical proximity between firms and their university partners is only of significance to reap benefits associated with direct assistance in problem solving. However, there is no support for the argument that co-location would enhance the probability of obtaining any of the other benefits from interaction with university (other than problem solving).

We have also provided evidence showing that for only a restricted range of benefits does the quality of research of the university partner is a critical factor in enhancing the probability that the firm assesses a benefit from interaction as important. This largely supports the argument that both top and low-ranked departments have important contributions to make with respect to the innovative activities of firms, in issues as varied as: fundamental understanding, access to information for new projects or processes, direct assistance in problem solving or recruitment, among others.

However, it is important to bear in mind that our sample of partnerships includes a large proportion of university partners in engineering fields. This may underlie our finding that top-ranked departments have a particular impact on benefits associated to the enhancement of 'downstream related activities'. This result points towards further research along the lines of expanding the sample of partnerships between university and industry beyond physical sciences and engineering, including interactions within the life sciences.

Finally, further research should address the extent to which the characteristics that shape the firms' assessment of benefits from university interactions as important differ between manufacturing and service firms. Since most of prior research has focused on the manufacturing sector, we know very little about service firms with regards to their patterns of interaction with university. We plan to extend the research initiated in this paper by looking in more detail at the differences between manufacturing and service firms with respect to their gains from interactions with university.

Bibliography

Abramovsky, L., R. Harrison, et al. (2006). "University Research and the location of Business R&D." Institute of Fiscal Studies Working Paper ***07/02****.*

Ahuja, G. (2000). "Collaboration networks, structural holes and innovation: a longitudinal study." Administrative Science Quarterly ***45****: 425-455.*

Arundel, A., G. Van de Paal and L. Soete (1995). PACE Report: Innovation Strategies of Europe's Largest firms: results of the PACE Survey for information Sources, Public Research, Protection of Innovation and Government Programmes. Final Report, MERIT, University of Limburg, Maastricht.

Arundel, A. and A. Geuna (2004). "Proximity and the use of public science by innovative European firms." Economics of Innovation and New Technologies ***13****(3): 559-580.*

Bercovitz, J.E.L. and M.P. Feldman (2007). "Fishing upstream: firm innovation strategy and university research alliances". Research Policy 36: 930-948.

Charles, D. (2006). "Universities as key knowledge infrastructures in regional innovation systems." Innovation ***19****(1): 117-130.*

Cleary, S. (1999). "The relationship between firm investment and financial status." Journal of Finance ***54****(673-692).*

Cohen, W. M. and D. A. Levinthal (1989). "Innovation and Learning: The Two Faces of R & D." The Economic Journal ***99****: 569-596.*

Cohen, W. M. and D. A. Levinthal (1990). "Absorptive capacity: A new perspective of learning and innovation." Administrative Science Quarterly ***35****(1): 128-152.*

Cohen, W. M., R. R. Nelson and J.P. Walsh (2002). "Links and impacts: The influence of public research on industrial R&D." Management Science ***48****(1): 1-23.*

D'Este, P. and P. Patel (2007): "University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry" Research Policy ***36****: 1295-1313.*

DTI. (2005). "UK Innovation Survey." Retrieved June, 2006, from http://www.dti.gov.uk/files/file9673.pdf.

Feldman, M. P. (1994). The Geography of Innovation. Amsterdam, Kluwer Academic Press.

Florida, R. (1999). "The role of the university: leveraging talent, not technology". Issues in Science and Technology 14 (4): 67-73.

*George, G., S. Zahra, et al. (2002). "The effects of business-university alliances on innovative performance: a study of publicly traded biotechnology companies." Journal of Business Venturing **17**(577-609).*

*Gibbons, M. and R. Johnston (1974). "The roles of science in technological innovation". Research Policy **3**: 220-242.*

Greene, W. H. (2000). Econometric Analysis. Upper Saddle River, New Jersey, Prentice-Hall.

Hughes, A., A. Cosh and X. Fu (2006). "UK plc: Just how innovative are we? Findings from the Cambridge-MIT Institute International Innovation Benchmarking project". The Cambridge-MIT Institute. www.cambridge-mit.org

*Jaffe, A. B. (1989). "Real effects of academic research." The American Economic Review **79**(5): 957-970.*

*Jansen, J., F. Van den Bosch, et al. (2005). "Managing potential and realised absorptive capacity: how do organisational antecedents matter?" Academy of Management Journal **48**(6): 999-1015.*

*Klevorick, A.K., R.C. Levin, R.R. Nelson and S.G. Winter (1995): "On the sources and significance of interindustry differences in technological opportunities", Research Policy **24**: 185-205.*

*Lane, P., B. Koka, et al. (2006). "The Reification of Absorptive Capacity: a critical review and rejuvenation of the construct." Academy of Management Review **31**(4): 883-863.*

*Laursen, K. and A.J. Salter (2004). "Searching high and low: what types of firms use universities as a source of innovation?" Research Policy **33**: 1201-1215*

*Link, A. L. and J. Rees (1990). "Firm size, university based research, and the returns to R&D." Small Business Economics **2**: 25-31.*

Long, S. and J. Freese (2006). Regression Models for Categorical Dependent Variables Using Stata, Stata Press.

*Mansfield, E. (1991). "Academic research and industrial innovation" Research Policy **20**: 1-22.*

*Mansfield, E. and J. Lee (1996). "The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R&D Support." Research Policy **25**: 1047-1058.*

*Motohashi, K. (2005). "University- industry collaborations in Japan; the role of new technology based firms in transforming the National Innovation System." Research Policy, **34**(583-594).*

Mowery, D.C., R.R. Nelson, B.N. Sampat and A.A. Ziedonis (2004). Ivory tower and *industrial innovation. University-industry technology transfer before and after the Bayh-Dole Act. California, Stanford Business Books.*

OECD (2002). Benchmarking industry-science relationships. OECD: Paris.

OECD (2003). Turning science into business, patenting and licensing at public research organisations. OECD: Paris.

*Oltra, M. and M. Flor (2003). "The Impact of Technological Oppotunities and Innovation Capabilities on Firm's Output Innovation." Creativity and Innovation Management **12**(3): 137-145.*

Rosenberg, N. (1991). "Critical issues in science policy research". Science and Public Policy 18 (6): 335-346.

*Rosenberg, N. (1992). "Scientific instrumentation and university research" Research Policy **21**: 381-390.*

*Rosenberg, N. and R.R. Nelson (1994). "American universities and technical advance in industry". Research Policy **23**: 323-348.*

*Rosenkopf, L. and A. Nerkar (2001). "Beyong local research: boundary-spanning, exploration, and impact in the optical disk industry." Strategic Management Journal **22**: 287-306.*

*Salter, A.J. and B.R. Martin (2001). "The economic benefits of publicly funded basic research: a critical review". Research Policy **30**: 509-532.*

*Schartinger, D., C. Rammer, et al. (2002). "Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants." Research Policy, **31**: 303-328.*

*Schmidt, T. (2005). "Absorptive Capacity- One Size fits all? A firm level analysis of absorptive capacity for different kinds of knowledge." ZEW Centre for European Economic Research Discussion Papers **No. 05-72**.*

*Storper, M. and A. Scott (1995). "The Wealth of Regions: Market Forces and Policy Imperatives in Local and Global Context." Futures **27**(5): 505-526.*

*Storper, M. and A. J. Venables (2004). "Buzz: face-to-face contact and the urban economy." Journal of Economic Geography **4**: 351-370.*

*Todorova, G. and B. Durisin (2007). "Absorptive Capacity: Valuing a Reconceptualisation." Academy of Management Review **32**(3): 774-786.*

Vega, J., A. Gutierrez-Gracia, et al. (2007). Apropriability, proximity, routines and innovation. DRUID Summer Conference, Copenhagen, CBS, Denmark.

*Veugelers, R. (1997). "Internal R&D expenditures and external knowledge sourcing." Research Policy, **26**(3): 303-315.*

*Williams, R. (2006). "Generalised Ordinal Logit/Partial proportional odds model for Ordinal Response Dependent Variables." Stata Journal **6**(1): 58-62.*

*Zahra, S. A. and G. George (2002). "Absorptive Capacity: a review, reconceptualisation, and extension." Academy of Management Review **27**(2): 185-203.*

Appendix

Table A1a: Variable Description

Variable Code	Description
Dependent Variables	
Understanding Improved understanding of a particular phenomenon	Takes the following values: 0 if the firm assesses the contribution to "understanding" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Information Sources of information suggesting new projects	Takes the following values: 0 if the firm assesses the contribution to "information" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Patents Generation of patents	Takes the following values: 0 if the firm assesses the contribution to "patents" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Problem Solving Assistance in problem solving	Takes the following values: 0 if the firm assesses the contribution to "problem solving" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Recruitment Recruitment of university postgraduates	Takes the following values: 0 if the firm assesses the contribution to "recruitment" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Training of firm's personnel Training of firm's personnel by university researchers	Takes the following values: 0 if the firm assesses the contribution to "training" as unimportant or slightly important; and 1 f it assesses it as moderately, very or extremely important.
Downstream Activities This variable is a composite measure using the information contained by the responses to the following three items: 'Contribution to the successful market introduction of new products/ processes'; 'Cost reduction in product or process development'; and 'Reducing the time required for completion of company's R&D projects'	Takes the following values: 0 if the firm assesses the contribution to "downstream activities" as unimportant or slightly important; and 1 if it assesses it as moderately, very or extremely important.
Independent Variables	
Firm Size	Natural logarithm of the number of employees in the firm
R&D intensity	No. of R&D employees/total no. of employees
Distance	Average distance (expressed in Km) for all the partnerships in which a company was involved (based on records from EPSRC collaborative grants over the period 1993-2003).
Part of larger company	Dichotomous variable equal to 1 if firm is a subsidiary or division of a larger firm, 0 otherwise.
Number of Partnerships	Natural logarithm of the number of partnerships in which the company was involved (based on the records from EPSRC collaborative grants over the period 1993-2003)
Continuous R&D	Dichotomous variable equal 1 if the firm reports

	having continuously engaged in R&D activities over the past two years (2002-2003)
Medium: Medium quality score	Dichotomous variable equal to 1 if the average value of the quality scores awarded to the departments with which the firm has established partnerships is between 5.5 and 6.49 (labelled as medium-quality score)
Top: High quality score	Dichotomous variable equal to 1 if the average value of the quality scores awarded to the departments with which the firm has established partnerships is 6.5 or above (labelled as high quality score)

Table A1b. Descriptive statistics for independent variables and correlation matrix

Independent Variables	Average	St. Dev.	Median	Mode	Min.	Max.	2.	3.	4.	5.	6.	7.	8.
1. N. of Projects (Ln)	1.34	0.82	1.09	0.69	0.69	5.61	0.063	**0.224**	**-0.231**	**0.355**	0.091	**0.240**	**0.190**
2. Distance (Km)	156.4	111.3	145.6	54.2*	0.14	569.9		0.037	-0.069	-0.010	-0.028	0.026	-0.020
3. Medium Quality Score	0.48	0.50	0.00	0.00	0	1			**-0.436**	0.065	0.050	0.063	0.085
4. Top Quality Score	0.17	0.37	0.00	0.00	0	1				**-0.112**	0.016	-0.011	**-0.114**
5. Firm Size (N. employees, Ln)	4.50	2.28	4.25	3.91	0	12.4					**-0.337**	**0.124**	**0.444**
6. R&D Intensity	0.23	0.32	0.08	0.0	0	1						**0.353**	**-0.126**
7. Continuous R&D	0.72	0.45	1.00	1.00	0	1							**-0.097**
8. Part of larger firm	0.59	0.49	1.00	1.00	0	1							**---**

*In bold, correlations significant at the 5% level. * There are multiple modes for this variable – the smallest one is indicated.*

Table A2: Dependent Variables: Assessment of Benefits from Interactions with universities (% of firms by category of assessment)

Categories	Understand.	Information	Problem Solving	Recruitment	Training	Patents	Downstream Activities
0 (not important or slightly important)	33	42	33	58	73	80	71
1 (moderately, very or extremely important)	67	58	67	42	27	20	29
Total	100%	100%	100%	100%	100%	100%	100%